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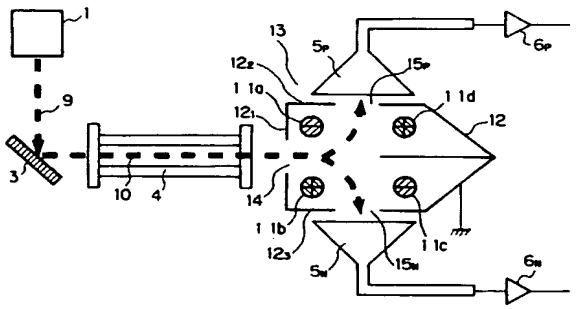
(54) Secondary ion mass spectrometer for analyzing positive and negative ions.

(57) A secondary ion mass spectrometer for analyzing secondary ions by separating and detecting positive and negative secondary ions generated from a sample (3) when the sample is irradiated with a high speed primary beam (9).

A sample is irradiated with a primary beam such as a high speed atom beam and secondary ions are emitted from the sample. The emitted secondary ions (10) are separated and detected by a quadrupole mass spectrometer (4). Downstream of the quadrupole mass spectrometer, a plurality of metallic rod electrodes (11a-11d) are provided in parallel with each other, some of which are supplied with a positive voltage and the rest with a negative voltage. An electrostatic shield (12) member surrounds the metallic rod electrodes. The secondary ions are separated into positive and negative secondary ions by the electric fields formed by the metallic rod electrodes. The separated secondary ions are respectively converted into currents by corresponding secondary electron multipliers (5p,5n) or Faraday cups.

Fig. 2



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The present invention relates to a secondary ion mass spectrometer, and more specifically, to a secondary ion mass analyzer for analyzing a sample by irradiating the sample with a primary beam, such as a high speed atom beam, and simultaneously separating and detecting both positively and negatively charged secondary ions emitted from the sample.

Fig. 1 schematically illustrates the structure of a secondary ion mass spectrometer of the prior art. In this figure, reference numeral 1 designates a high speed beam source for emitting a high speed atom; 2 an analyzing tube; 3 a sample; 4 a quadruple mass spectrometer; 5 a secondary electron multiplier; 6 an amplifier; 7 a recorder; 8 a vacuum pump; 9 a high speed atom beam; and 10 secondary ions generated when the sample is irradiated with the high speed atom beam.

This secondary ion mass spectrometer of the prior art operates as follows. An analyzing tube 2 and a quadrupole mass spectrometer 4 are sufficiently evacuated with a vacuum pump 8. A beam source 1 emits a high speed atom beam 9 to irradiate a sample 3. Secondary ions 10 are emitted from the sample 3 which is irradiated and bombed by the high speed beam 9 and these ions are discriminated by the quadrupole mass spectrometer 4, whereby only the secondary ions having a particular mass are selected and enter a secondary electron multiplier 5. Secondary ions 10 are converted into electrons equivalent to the input secondary ions in secondary electron multiplier 5 and the output is fed through an amplifier 6 and finally recorded by a recorder 7.

Such a secondary ion mass spectrometer is used for mass analysis of secondary ions generated from a solid surface of a sample irradiated with a high speed beam. This analyzing method provides extremely high sensitivity in comparison with other surface analyzing methods such as Auger electron spectroscopy and X-ray electron spectroscopy, and is characterized by its ability to analyze all the elements arranged in the periodic table and isotopes. Particularly, a high speed atom beam having energy of several hundred electron volts to several kiloelectron volts is suitable for mass analysis because it is electrically neutral and therefore is not influenced by a charged insulator, and the width of orbit of the atom beam remains constant the atom beam is not influenced by space charges.

However, a secondary ion mass spectrometer of the prior art does not have a function to separate both positively and negatively charged secondary ions, although both positively and negatively charged secondary ions are simultaneously emitted from a sample. Therefore, positively charged secondary ions cannot be detected when negatively charged secondary ions are detected, and vice versa. Accordingly, when it is required to obtain mass spectra of secondary ions charged in different polarities for one sample, analysis must be conducted twice, resulting in complexity of operation and a lack of swiftness and reliability of manipulation.

In view of the foregoing problems of the prior art, it is an object of the present invention to provide a secondary ion mass spectrometer having a function to simultaneously separate and detect both positively and negatively charged secondary ions emitted from a sample.

According to the first aspect of the present invention, for the purpose of achieving the object mentioned above, there is provided a secondary ion mass spectrometer comprising a mass-separating means for mass-separating secondary ions emitted from a sample irradiated with a high speed primary beam, and a charge separating means for receiving the secondary ions separated by the mass-separating means to charge-separate such secondary ions into positively charged and negatively charged secondary ions so as to utilize currents equivalent to the levels of the separated positive and negative secondary ions.

According to the second aspect of the present invention, there is provided a secondary ion mass analyzer comprising (1) a means for irradiating a sample with a high speed primary beam, (2) a mass-separating means for separating and detecting the secondary ions emitted from the sample, (3) an ion separator means arranged downstream of the mass-separating means and including a plurality of metal electrodes arranged in parallel with each other and supplied with positive and negative voltages and an electrostatic shielding means surrounding the metal electrodes and having an ion entering hole facing the mass-separating means and ion exiting holes, and (4) ion-current converting means disposed to face the respective ion exiting holes.

In a preferred embodiment of the present invention, four metal electrodes are provided and respectively arranged in parallel with each other at four apices of a rectangle. A positive voltage is applied to the electrodes located on one diagonal line of the rectangle while a negative voltage is applied to the electrodes located on the other diagonal line thereof.

In another embodiment of the present invention, two metal electrodes are used and a positive voltage is applied to one metal electrode while a negative voltage is applied to the other metal electrode.

The ion-current converting means is a secondary electron multiplier or a Faraday cup.

In a secondary ion mass spectrometer of the present invention, in order to detect secondary ions

comprising positively and negatively charged secondary ions emitted from a sample, the positively and negatively charged secondary ions pass through a charge separating means for separating the positively and negatively charged secondary ions with electric fields formed by metallic electrodes to which positive and negative voltages are applied. This enables simultaneous detection of both secondary ions, thereby realizing swift and efficient mass analysis. Therefore, a secondary ion mass spectrometer of the present invention is very different from that of the prior art in structure and operation.

The above and further objects and features of the present invention will become more apparent from the following detailed description with reference to the accompanying drawings.

Fig. 1 schematically illustrates the structure of a secondary ion mass analyzer of the prior art.

Fig. 2 schematically illustrates the structure of the first embodiment of a secondary ion mass analyzer according to the present invention.

Fig. 3 schematically illustrates the structure of the second embodiment of a secondary ion mass analyzer according to the present invention.

Fig. 2 schematically illustrates the structure of the first embodiment of a secondary ion mass analyzer according to the present invention. A high speed atom beam source 1 generates a high speed atom beam 9 and a sample 3 is irradiated with this atom beam.

Positive and negative secondary ions 10 generated when the sample 3 is irradiated with the beam 9 are discriminated by a quadruple mass spectrometer 4 and separated into positive ions and negative ions by a charge separator 13. The separated positive and negative ions are then input to corresponding secondary electron multipliers or Faraday cups 5_P, 5_N, which in turn convert those ions into currents corresponding to the quantity of the input secondary ions. These currents are then amplified by amplifiers 6_P, 6_N and are recorded as mass spectra by a recorder (not illustrated).

The charge separator 13 is provided with four metallic rod electrodes 11a, 11b, 11c, 11d arranged in parallel with each other in the direction perpendicular to the paper surface and an electrostatic shield member 12 surrounding the metallic rod electrodes. These four metal rod electrodes 11a, 11b, 11c, 11d are respectively disposed at the apices of a rectangle. Of the wall surfaces of the electrostatic shielding member 12, wall surface 12_1 facing the quadruple mass spectrometer 4 has a secondary ion entering hole 14, while the two wall surfaces 12_2, 12_3 adjacent to wall surface 12_1 have secondary ion exiting holes 15_P, 15_N. Facing secondary ion exiting hole 15_P, secondary electron multiplier or Faraday cup 5_P is provided in order to detect positive secondary ions separated by charge separator 13, and secondary electron multiplier or Faraday cup 5_N facing secondary ion exiting hole 15_N is provided to detect negative secondary ions. Among the four metallic column electrodes 11a to 11d, a positive voltage is applied from a power source to two electrodes disposed on one diagonal line while a negative voltage is applied to the remaining two electrodes disposed on the other diagonal line. Electric fields are thus generated within the electrostatic shield member 12 to separate positive and negative ions respectively in different directions.

Specifically, positive and negative secondary ions 10 discriminated by the quadrupole mass spectrometer 4 enter the electrostatic shield member 12 through the secondary ion entering hole 14. A negative voltage is applied, for example, to two electrodes 11a, 11c disposed on one diagonal line of a rectangle formed by the four metallic rod electrodes 11a, 11b, 11c, 11d, while a positive voltage is applied to the remaining two electrodes 11b, 11d. The positive secondary ions pass through the secondary ion entering hole 14 and then through the ion incident plane formed by metallic rod electrodes 11a, 11b, and are directed to the upper side of Fig. 2 by the electric field formed by the four metallic rod electrodes 11a to 11d, while the negative secondary ions are directed to the lower side of Fig. 2. The positive secondary ions thus separated pass through the secondary ion exiting plane formed by metallic rod electrodes 11a, 11d and then through secondary ion exiting hole 15_P of the electrostatic shield member 12 and then enter secondary electron multiplier or Faraday cup 5_P.In a similar manner, the negative secondary ions pass through the secondary ion exiting plane formed by metallic rod electrodes 11b, 11c and then through secondary ion exiting hole 15_N and then enter secondary ion multiplier or Faraday cup 5_N.

The positive and negative secondary ions entering the secondary electron multipliers or Faraday cups 5_P, 5_N are respectively converted into currents corresponding to the quantity of secondary ions and these currents are then amplified by amplifiers 6_P, 6_N. The outputs of the amplifiers 6_P, 6_N are supplied to a recorder, whereby the quantity of positive and negative secondary ions is respectively recorded as mass spectra.

According to the result of a computer simulation, in the case where the intervals between the metallic rod electrodes 11a, 11b, 11c, 11d are set at about several centimeters and voltages of ± 50V are applied to these metallic rod electrodes to form electric fields in the electrostatic shield member 12, it has been confirmed that secondary ions of 10 to 35 electron volts are distinctively separated to posi-

tive and negative secondary ions, which respectively enter the corresponding secondary electron multipliers or Faraday cups 5_P, 5_N.

Fig. 3 schematically illustrates the structure of the second embodiment of a secondary ion mass analyzer according to the present invention. The charge separator 13 comprises two metallic rod electrodes 11e, 11f which are arranged in parallel with each other in the direction perpendicular to the paper surface and an electrostatic shield member 12 having three wall surfaces surrounding the metallic rod electrodes. Wall surface 12_1 facing quadrupole mass spectrometer 4 has a secondary ion entering hole 14 and the two wall surfaces 12_2, 12_3 adjacent to wall surface 12_1 respectively have secondary ion exiting holes 15_P, 15_N.Facing secondary ion exiting holes 15_P, 15_N, secondary electron multipliers or Faraday cups 5_P, 5_N are respectively disposed. A power supply is connected such that a positive voltage is applied to one electrode 11_f and a negative voltage to the other electrode 11_e.

With a process similar to that of the first embodiment illustrated in Fig. 2, positive and negative secondary ions are discriminated by the quadrupole mass spectrometer 4. The discriminated secondary ions enter the electrostatic shield member 12 through the secondary ion entering hole 14. The positive secondary ions pass through the plane formed by metallic rod electrodes 11_e, 11_f and are directed to the upper side of the figure due to the electric field generated by the same electrodes, while the negative secondary ions are directed to the lower side thereof. As a result, the positive and negative secondary ions are respectively separated in different directions. The separated secondary ions enter corresponding secondary electron multipliers or Faraday cups 5_P, 5_N, respectively, and are then converted into currents equivalent to the levels of the respective ions. These currents are respectively amplified by amplifiers 6_P, 6_N and recorded as mass spectra by the recorder.

As explained above in detail, according to a secondary ion mass spectrometer of the present invention, both positive and negative secondary ions emitted in combination are separated in different directions and can thereby be detected simultaneously, enabling secondary ion mass spectra of the positive and negative secondary ions to be obtained completely at one time. As a result, mass spectrum analysis can be done more swiftly and more reliable data can be obtained than in the prior art.

Claims

1. A secondary ion mass spectrometer comprising: a mass-separating means for separating secondary ions emitted from a sample when said sample is irradiated with a high speed primary beam; and a charge separating means for receiving the secondary ions mass-separated by said mass-separating means to separate such ions into positive secondary ions and negative secondary ions for utilization of currents corresponding to the charge-separated positive and negative secondary ions.

2. A secondary ion mass spectrometer according to claim 1, wherein said charge separating means comprises an electrode group including an electrode to which a positive voltage is applied and an electrode to which a negative voltage is applied, and an electrostatic shield means surrounding said electrode group, said electrostatic shield means being provided with a secondary ion entering hole through which the secondary ions separated by said mass-separating means pass and secondary ion exiting holes through which the positive and negative secondary ions separated by said electrode group pass to the outside of said shield member.

3. A secondary ion mass spectrometer comprising: a means for irradiating a sample with a high speed primary beam; a mass-separating means for separating and detecting secondary ions emitted from said sample; an ion separator means arranged downstream of said mass-separating means and including a plurality of metal electrodes arranged in parallel with each other and supplied with positive and negative voltages to separate the secondary ions into positive and negative secondary ions, and an electrostatic shield means surrounding said metal electrodes and having an ion entering hole facing said mass-separating means and ion exiting holes; and an ion-current converting means for converting the positive and negative secondary ions coming out of said exiting holes to currents equivalent to the levels of the respective secondary ions.

4. A secondary ion mass spectrometer according to claim 3, wherein the number of said metal electrodes is four, said metal electrodes are disposed in parallel with each other at four apices of a rectangle and a positive voltage is applied to two electrodes located on one diagonal line of said rectangle while a negative voltage is applied to the remaining two electrodes located on the other diagonal line.

5. A secondary ion mass spectrometer according to claim 4, wherein said ion-current converting

means comprises secondary electron multipliers.

6. A secondary ion mass spectrometer according to claim 4, wherein said ion-current converting means comprises Faraday cups.

7. A secondary ion mass spectrometer according to claim 3, wherein the number of said metal electrodes is two, and a positive voltage is applied to one of said metal electrodes while a negative voltage is applied to the other electrode.

8. A secondary ion mass spectrometer according to claim 7, wherein said ion-current converting means comprises secondary electron multipliers.

9. A secondary ion mass spectrometer according to claim 7, wherein said ion-current converting means comprises Faraday cups.

Fig. 1

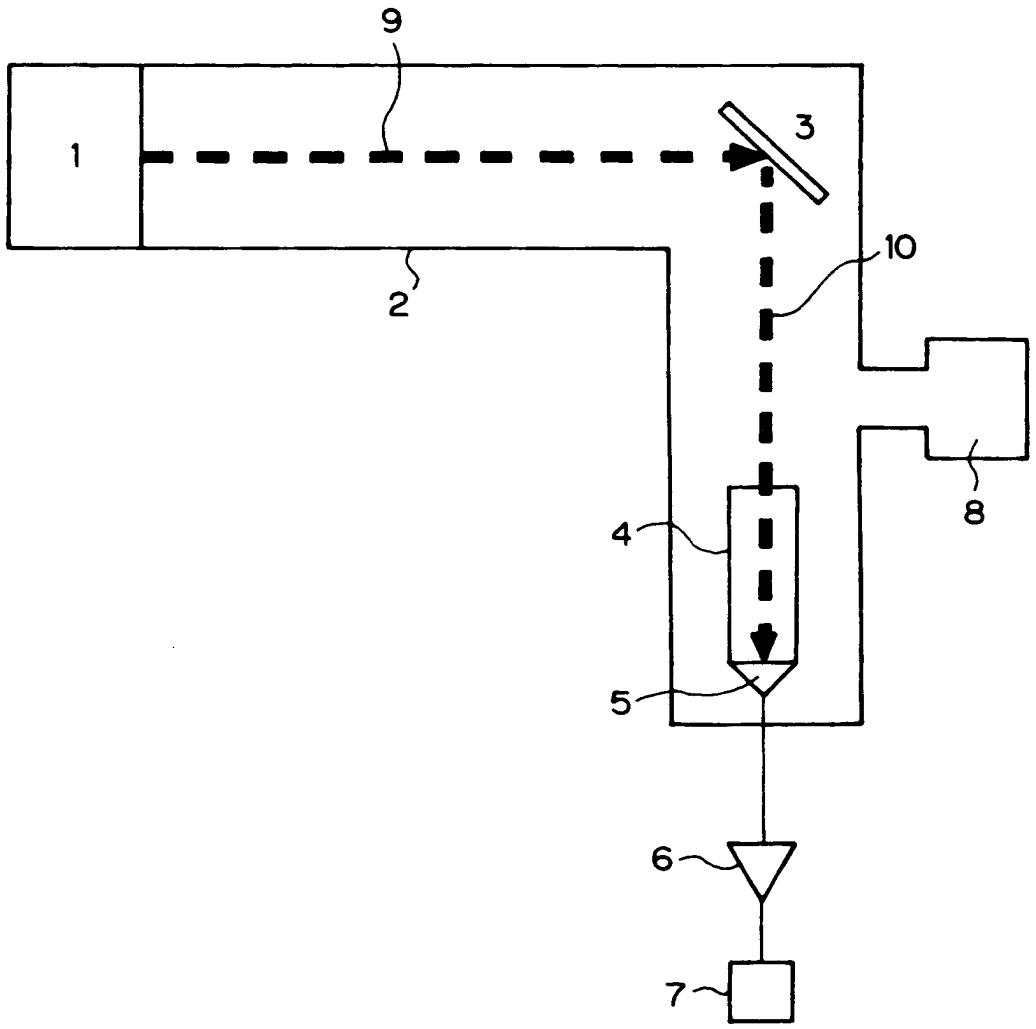


Fig. 2

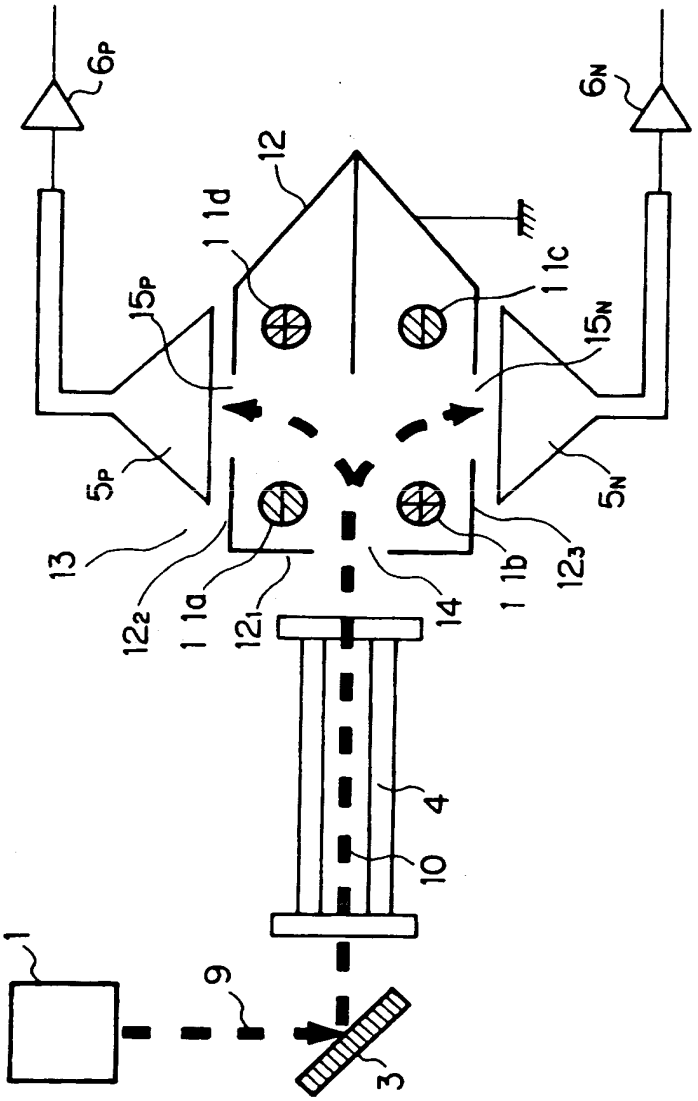
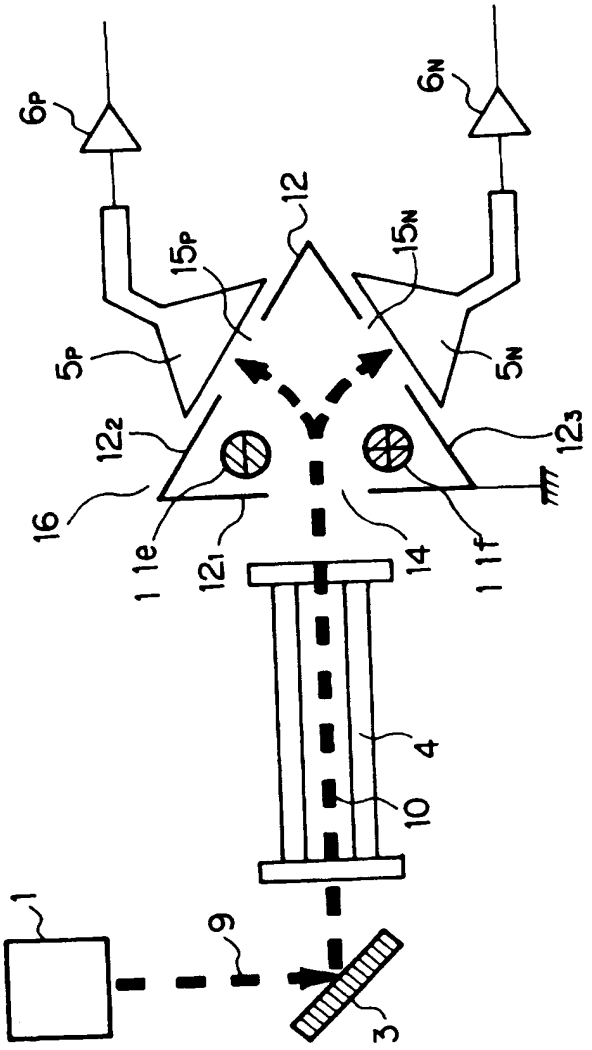


Fig. 3



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EUROPEAN SEARCH REPORT

Application Number

EP 93 10 3506

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y A	FR-A-2 246 976 (HEWLETT-PACKARD) * page 1, last paragraph - page 2; claim 1; figure 1 *	1 3	H01J49/02
Y	PATENT ABSTRACTS OF JAPAN vol. 11, no. 217 (E-523)14 July 1987 & JP-A-62 037 860 (NIPPON TELEGR. AND TELEPH.) 18 February 1987 * abstract *	1	
A	US-A-4 988 867 (B. L. LAPRADE) * column 1, line 45 - line 62; figures 1,2 *	1,3	
A	INTERNATIONAL LABORATORY vol. 18, no. 5, June 1988, FAIRFIELD CT US pages 26 - 32 D. WILLIAMS 'AN AUTOMATED HYBRID MASS SPECTROMETER WITH A USER-ORIENTED INTERFACE'	1,3	
A	FR-A-2 339 249 (UNIVERSITY OF VERGINIA) * page 10, line 5 - page 11, line 17; figures 1,4 *	1,3	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	07 JUNE 1993	HULNE S.L.

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